Australian Government
Department of Defence
Defence Science and
Technology Organisation

Reduced Sensitivity RDX (RS-RDX) Part II: Sympathetic Reaction

Ian J. Lochert, Mark D. Franson and Brian L. Hamshere

Weapons Systems Division
Systems Sciences Laboratory

DSTO-TR-1941

ABSTRACT

Australian-manufactured Grade A RDX has been proven to be a Reduced Sensitivity grade of RDX. That is, when used in cast-cured PBX formulations, the PBX is intrinsically less sensitive to shock stimuli than if conventional RDX is used. The implications for insensitive munitions compliance may be significant, particularly in sympathetic reaction scenarios. This work assesses the sympathetic response of ADI Grade A RDX in a standard polymer-bonded explosive formulation in a generic test unit and compares it with formulations containing RDX produced by SNPE (France) and Dyno Nobel (Norway). Additional work was performed to assess the sympathetic reaction of uncased charges of PBXN-109 containing standard Type II RDX. This data was primarily required for modelling studies.

Published by

DSTO Defence Science and Technology Organisation
PO Box 1500
Edinburgh South Australia 5111 Australia

Telephone: (08) 8259 5555
Fax: (08) 8259 6567

AR-013-794
November 2006

APPROVED FOR PUBLIC RELEASE

Reduced Sensitivity RDX (RS-RDX) Part II: Sympathetic Reaction

Executive Summary

Australia's Insensitive Munitions policy (DI(G) LOG 07-10) requires that all new explosives ordnance satisfies a number of safety criteria, including a low severity response in sympathetic reaction scenarios. That is, if one ordnance item accidentally detonates, then adjacent items should have a response no greater than Type III (explosion). One significant factor in weapons design to allow compliance with this requirement is for the explosive formulation to have low sensitivity to shock initiation. Reduced Sensitivity grades of the high explosive RDX (RS-RDX) have been shown to result in polymer-bonded explosive (PBX) formulations that are intrinsically less sensitive to shock initiation than conventional RDX grades. Australian-manufactured RDX has been shown to be an RS-RDX material.

This paper compares different RDX grades in a conventional PBX formulation under sympathetic reaction scenarios using generic test items. It is demonstrated that PBX formulations containing RS-RDX grades can provide benefits to weapons designers in terms of response to sympathetic reaction events. This finding will be of significance to the international community as policies for the use of RS-RDX are developed. PBX-filled weapons are of increasing importance to the Australian Defence Department. This report demonstrates an immediately available method to improve the safety of such items.

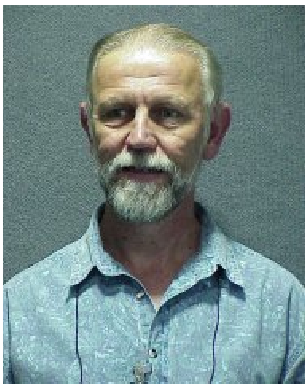
Authors

Dr Ian J Lochert
Weapons Systems Division

In 1998, following completion of PhD and post-doctoral studies, Ian joined the Explosives Group at DSTO Edinburgh. Since this time he has worked in a number of areas including synthesis and characterisation of FOX-7, formulation and testing of polymer-bonded explosives and investigations into Reduced Sensitivity RDX. In 2003/2004 Ian was posted to the Energetic Materials Branch of the US Air Force Research Laboratory where he worked on Multiphase Blast Explosives, this research area is now continuing at DSTO.

Mark D Franson
Weapons Systems Division

Mark joined Weapons Systems Division with a Bachelor of Applied Chemistry degree in 2002. He spent several years previously at the Ian Wark Research Institute (UniSA) conducting academic research into polymer science and surface modification. Currently Mark is working with the development of new polymer-bonded explosives while studying toward his Masters degree in Defence Technologies.



Brian L Hamshere
Weapons Systems Division

Since 1977 Brian Hamshere has worked in the area of composite energetic materials. Initially, on solid composite rocket propellants including high burn rate, low signature and low vulnerability formulations, and more recently on formulating and characterising polymer-bonded explosives. This latter work has included developing technical expertise concerning the explosive fill for the Penguin ASM warhead, investigating and comparing the shock sensitivity of different grades of the explosive compound RDX and testing reduced sensitivity forms of this material in simulated ordnance. Brian retired from DSTO in September 2006..

Contents

Abbreviations

ADI	ADI Limited
ARX	Australian research explosive
DOA	Dioctyl adipate
DSTO	Defence Science and Technology Organisation
HMX	Cyclotetramethylenetetranitramine
HTPB	Hydroxyl terminated polybutadiene
IM	Insensitive Munitions
IPDI	Isophorone diisocyanate
I-RDX	Insensitive RDX (SNPE)
LSGT	Large Scale Gap Test
MRL	Materials Research Laboratory (DSTO)
MSIAC	Munitions Safety Information Analysis Center
NIMIC	NATO Insensitive Munitions Information Center
NOL	Naval Ordnance Laboratory, WhiteOak. Later Naval Surface Warfare Center.
PBX	Polymer-bonded explosive
PBXN	PBX formulation qualified for in service use by the US Navy
RDX	Cyclotrimethylenetrinitramine
RO	Royal Ordnance PLC, Bridgwater UK
RS-RDX	Reduced Sensitivity RDX
SEM	Scanning electron microscopy
SME	SNPE Matériaux Énergétiques
SNPE	Société Nationale des Poudres et Explosifs

1. Introduction

It has been shown [1-3] that a form of the high explosive RDX can be produced, under certain recrystallisation conditions, which results in a polymer-bonded explosive (PBX) that is intrinsically less sensitive to shock stimuli than a PBX made using conventional RDX grades. The French company SNPE were the first to report such observations [2, 3] and named their material Insensitive RDX (I-RDX). Work conducted at DSTO [4, 5] has shown that ADI[1] Grade A RDX [6] has equivalent properties to I-RDX and is classified as a Reduced Sensitivity RDX (RS-RDX), which is the generic term adopted for these less sensitive grades of RDX.

This benefit that RS-RDX imparts to cast-cured PBXs has significant implications in the area of Insensitive Munitions (IM) and should best be realised in sympathetic detonation scenarios. Response to heavy fragment impact may also be reduced [7].

In order to determine whether the reduced shock sensitivity of cast-cured PBXs containing RS-RDX does translate to improvements in sympathetic detonation scenarios, an experimental study was conducted. The response of PBXN-109 type formulations containing two different RS-RDX grades (ADI Grade A and SNPE I-RDX[2,3]) and a conventional grade of RDX (Dyno Nobel Type II) in generic test units was compared. Subsequent to the above study similar work was conducted on the response of PBXN-109 uncased charges in a sympathetic reaction scenario. This study was undertaken primarily to provide input to modelling work. The results of both studies are reported herein whilst the preliminary modelling work on the uncased charges has been reported elsewhere [8].

2. Background

2.1 Reduced Sensitivity RDX

The work detailed in this report was first presented to the international community in 2003 at the Sixth Australian Ordnance Symposium (Parari) [9], and is still the only reported experimental study of sympathetic detonation involving RS-RDXs. Since this work was carried out there have been significant further developments in the area of RS-RDX from a range of commercial and defence bodies [10-13].

---

[1] In October 2006 ADI Limited became Thales Australia however the terminology ADI is used throughout this report as it was valid when the work was performed.

[2] When this material was purchased the supplier was known as SNPE. Since January 2004, following a merger of SME (a SNPE subsidiary), NEXPLO Bofors and NEXPLO Vhitavuori, the supplier is now known as Eurenco. Throughout this report the terminology SNPE I-RDX will be retained.

[3] Reduced Sensitivity RDX grades (RS-RDXs) were originally referred to as Insensitive RDX or I-RDX; however, this terminology has been trademarked by Eurenco.

In 2003 NIMIC (now MSIAC) nations held a workshop (Joint NIMIC/AC326 SG 1 RS-RDX Technical Meeting) to review developments in the area of RS-RDX and also to develop a standard analytical method for differentiating between regular RDX and RS-RDX. The primary outcome of this meeting was the establishment of a multi-nation round-robin testing programme [13, 14] in which DSTO participated and which included the testing of ADI RDX. Dyno Nobel has also claimed to be producing RS-RDX and their material was also included in the round-robin testing.

Recent developments in the RS-RDX field were extensively reported at the 2004 NDIA Insensitive Munitions and Energetic Materials Symposium. Reports included demonstrations that RS-RDX can reduce the sensitivity of PBXN-109 to fragment impact and shaped charge jet attack [10], further shock sensitivity studies [11], ageing studies [12] and initial work towards reduced sensitivity HMX [15].

2.2 Sympathetic Reaction

The sympathetic reaction test is described in MIL-STD-2105B [16] as "..detonating one munition (donor) adjacent to one or more like munitions (acceptors). The objective is to evaluate the likelihood that a detonation reaction may be propagated from one unit to another…". The generally accepted outcome [17] to pass the test is a Type III (explosion) reaction or better. The sympathetic detonation test is often extremely difficult to pass, particularly for larger munitions. For example, the Penguin anti-ship missile warhead filled with PBXN-109 fails the test [18].

2.3 Sympathetic Reaction and Reduced Sensitivity RDX

The only published data relating the properties of a PBX formulation containing RS-RDX to improvements in sympathetic reaction response is contained in a conference paper by authors from SNPE [7]. For generic test units containing PBXN-109, SNPE have stated that the formulation containing I-RDX will pass a sympathetic reaction test for a test unit diameter of ~125 mm, whereas for conventional RDX the pass diameter is only ~75 mm. These results are understood to be from simulations based on small-scale experimental results.

2.4 DSTO Sympathetic Reaction Test

To examine the response of PBX formulations in sympathetic reaction scenarios the authors developed a test methodology and associated test hardware. The concept was to design a series of experiments that would produce data representative of PBX-filled steel-cased ordnance in sympathetic reaction scenarios. Rather than simply examine the acceptor responses in typical storage configurations, tests were performed at a range of separations to determine the responses at different distances and compare the results with pass/fail criteria. Comparative analysis was used to determine any differences between the three different grades of RDX. The methodology involved the use of identical cased charges for both donors and acceptors with one donor and two acceptor charges per test. The generic test units, described in detail in Section 3, were designed for simplicity of manufacture and compatibility with any future modelling requirements, and were based

on recommendations from NIMIC and results reported in the SNPE conference paper [7]. The subsequent testing of uncased charges of PBXN-109, described in Appendix A, followed a similar procedure.

3. Hardware and Materials

3.1 Generic Test Units

The generic test units (GTU) were manufactured from mild steel as detailed:

a) Bodies – manufactured from 120.7 mm OD x 101.6 mm ID (9.5 mm wall) hydraulic (seamless) steel pipe, 300 mm long. A base plate 9.5 mm thick was welded to one end of the pipe. The open end had a thread machined to the external surface to accept the end caps
b) End caps (acceptors) – machined mild steel, 9.5 mm wall thickness and 25 mm internal length, threaded to screw over open end of body
c) End caps (donors) – identical to end caps for the acceptor except for a 52 mm diameter hole located centrally in the top surface to accept the booster.

Two additional generic test unit bodies were manufactured for side initiation tests, each had a 52 mm diameter hole machined either 100 mm or 200 mm from the top of the body to the centre of the hole. Acceptor end caps were used with these bodies.

3.2 Energetic Materials

3.2.1 RDX Samples

Table 1. RDX grades used in the formulations

Manufacturer	Description	Lot No.
ADI – Mulwala	Type I, Grade A	13808A
SNPE	I-RDX	0719S00
Dyno Nobel	CXM-7 (Type II, Class 1 + Class 5)	NSI 00L001-003
RO - Bridgwater	Type I, Class 5	1659

Three different grades of RDX, as detailed in Table 1, were used for comparative evaluation in the PBXN-109 formulations. Class 5 (fine) RDX from Royal Ordnance was also used in the formulations containing ADI and SNPE RDX, as required by the military specification for PBXN-109 (MIL-E-82886(OS), Explosive, Plastic-Bonded, and Cast PBXN-109). CXM-7 was supplied as a blend of RDX Class 1 and Class 5 coated with the plasticiser dioctyl adipate, in compliance with the military specification.

3.2.2 PBXN-109 Formulations

The PBXN-109 formulation containing Dyno Nobel CXM-7 and filled into the GTUs was manufactured at ADI's Mulwala facility in a 30 gallon Baker-Perkins planetary action

mixer with a batch size of 140 kg. The other formulations were manufactured at DSTO Edinburgh in a 5 gallon Baker-Perkins planetary action mixer with batch sizes 24 to 33.5 kg.

X-ray examination of the filled GTUs, along with the very consistent net explosive weight of 4.0 ± 0.05 kg confirmed that GTUs were free of significant voids. The x-ray examination did indicate the presence of minor discontinuities in some filled GTUs; however, only five of these were acceptor charges. Analysis of the results gave no indication that these five acceptor charges responded unusually.

All non-energetic ingredients in the PBX formulations, except as described below, had been shown to be compliant with the military specification, MIL-E-82886(OS). The exceptions, in the formulations containing ADI and SNPE RDX, were:

- The aluminium powder was Grade 75L (comparable with X-81) Lot L002146P from Eckart Aust P/L. The manufacturer's specification is 95-100% < 45 μm by sieve analysis. Particle size analysis at DSTO on a Malvern Mastersizer 2000 indicated a volume median diameter of 22.6 μm and a span of 1.89.
- The isophorone diisocyanate was supplied by Aldrich (Product code 31,762-4)
- The dioctyl adipate was DSTO stock sourced from Corflex.

These ingredients were considered to be, for the purpose of this project, equivalent to the Mil-Spec compliant ingredients. In other words, the three formulations were essentially identical, the only significant difference being the source of RDX. The three formulations are designated as follows:

Table 2. PBX formulation details

Designation	RDX
PBXN-109	CXM-7
ARX-2014/M1	ADI Grade A (59%) + RO Class 5 (5%)
ARX-2014/M5	SNPE I-RDX (59%) + RO Class 5 (5%)

3.2.3 Explosives Train

In all experiments, the donor charges, filled with PBXN-109, were initiated by L2A1 low-voltage detonators fired onto pentolite (50:50) boosters (L=D=50 mm).

3.3 Other Trial Hardware

3.3.1 Witness Plates

Witness plates beneath the generic test units were 20 mm thick x 270 x 270 mm 250 grade mild steel plate. The vertical witness plates used to investigate fragment penetration from the GTUs were 9.5 mm thick and either 300 x 300 mm or 600 x 600 mm mild steel plate.

3.3.2 Fragment Capture Packs

Caneite fragment capture packs were used to capture fragments from a single shot of a GTU. The packs were made up of caneite sheets and were nominally 300 x 300 x 1500 mm. The packs were stacked three high and four deep.

4. Trial Outline

4.1 Sympathetic Reaction Experiments

The sympathetic reaction tests were performed using the generic test units filled with PBXN-109 type formulations as described in Section 3. The donor units were always filled with standard PBXN-109. Acceptors were filled with standard PBXN-109, ARX-2014/M1 or ARX-2014/M5. The configuration of the hardware is shown in Figures 1 and 2. The charges each contained 4.0 ± 0.05 kg of PBXN-109 or ARX-2014 (M1 & M5).

Figure 1. Sympathetic reaction trial configuration (GTUs)

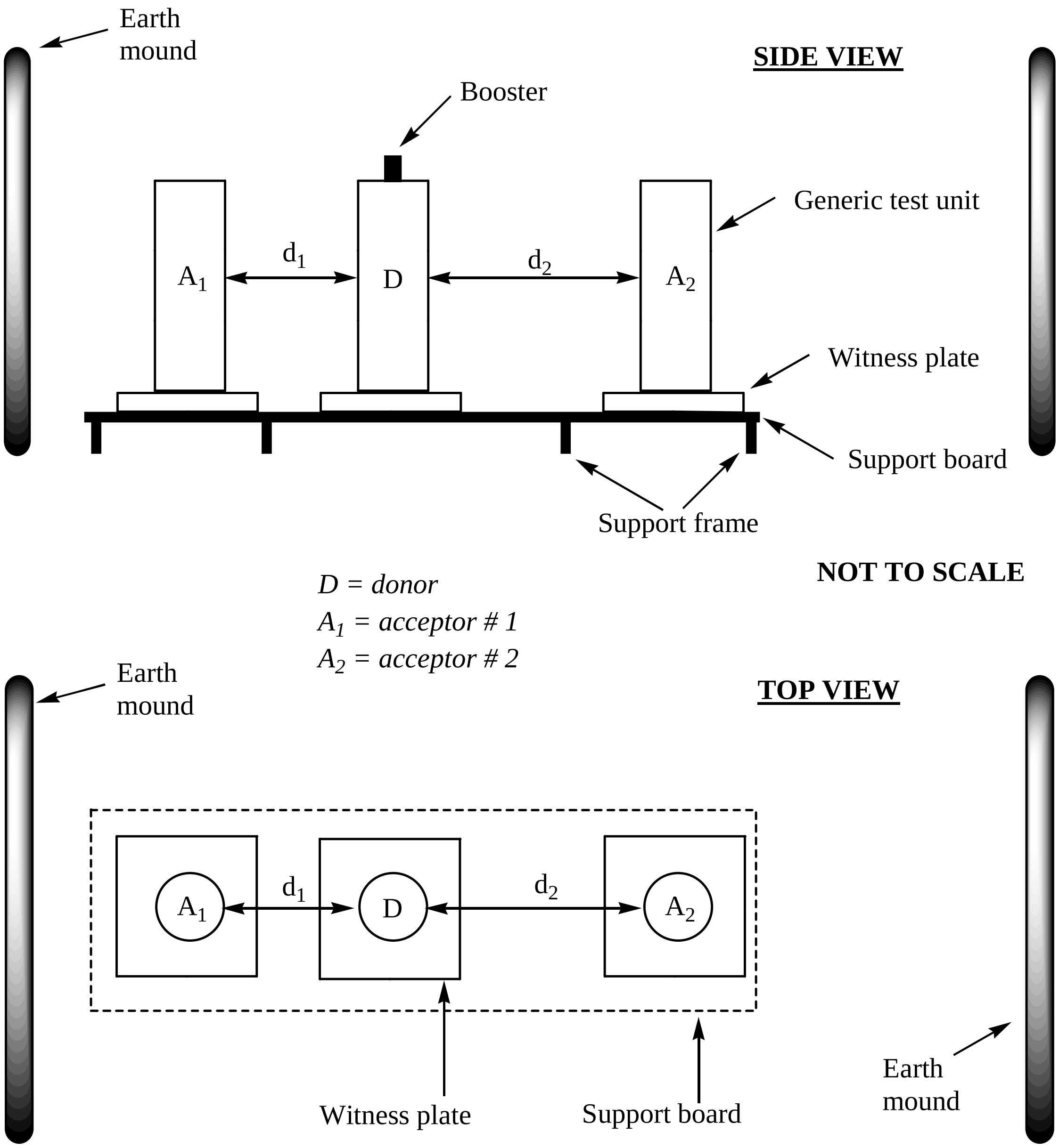


Figure 2. Schematic views of sympathetic reaction trial configuration

4.2 Additional Experiments

Whilst the sympathetic detonation experiments were the primary focus of the first trial, three other experiments were also performed to support the primary activity.

4.2.1 Side Initiation Experiments

Given that the acceptor charges are impacted on the side of the charge by a combination of fragments and shock from the donor charge, it was decided to confirm whether a GTU

that detonated following initiation from the side would result in a clean hole being punched in the witness plate. Two special GTUs were produced as described in Section 3 with a hole in the side of each unit to accept a booster at either one or two thirds of the distance from the top of the explosive fill (Figures 3a & b). These were fired individually on top of standard witness plates. The GTUs were both filled with ARX-2014/M1.

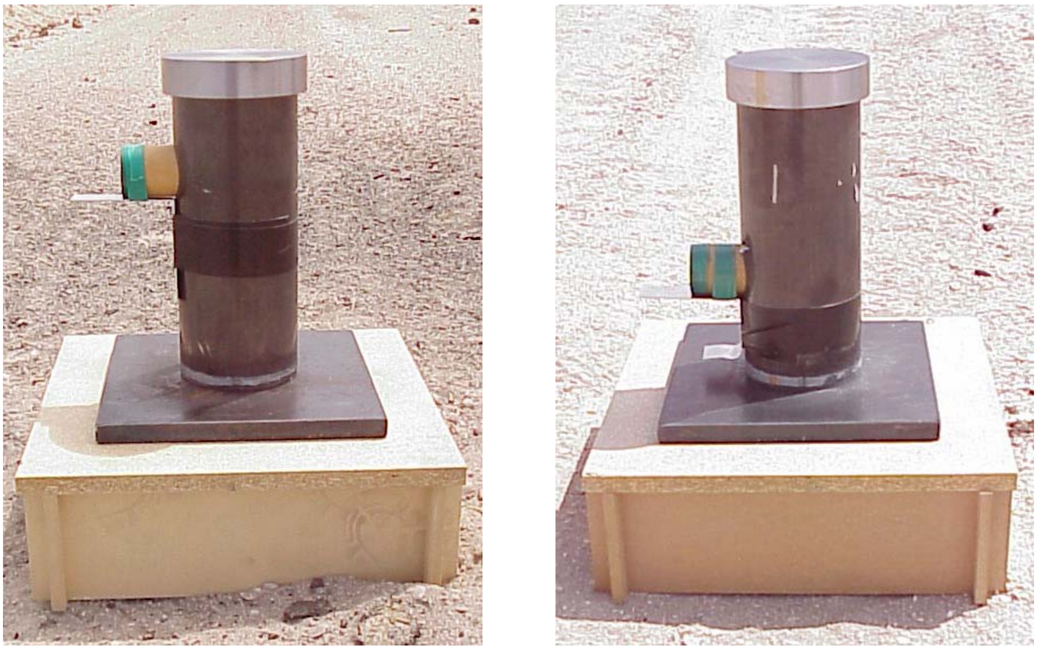


Figure 1a & b. Side initiation test configuration

4.2.2 Fragment Penetration Experiments

It was unknown how far the acceptor units had to be from the donor before fragments would stop penetrating the charge. To determine approximately what this separation distance was and whether it related to a change in response of the acceptors, penetration experiments were performed. During the course of the sympathetic detonation trial, vertical witness plates of the same thickness as the GTU walls (9.5 mm) were placed (Figure 4) at various distances from the donor charges and the effects of the fragments observed.

Figure 4. Fragment penetration test configuration

4.2.3 Fragment Capture Experiment

A single experiment was designed (Figures 4 & 5) to capture a sample of the fragments produced by the donor. A stack of 12 caneite fragment capture packs were placed 3 m from the donor charge, which was filled with standard PBXN-109. The purpose of recovering fragments from a donor charge was to assist in the understanding of the relationship between fragment penetration and acceptor response.

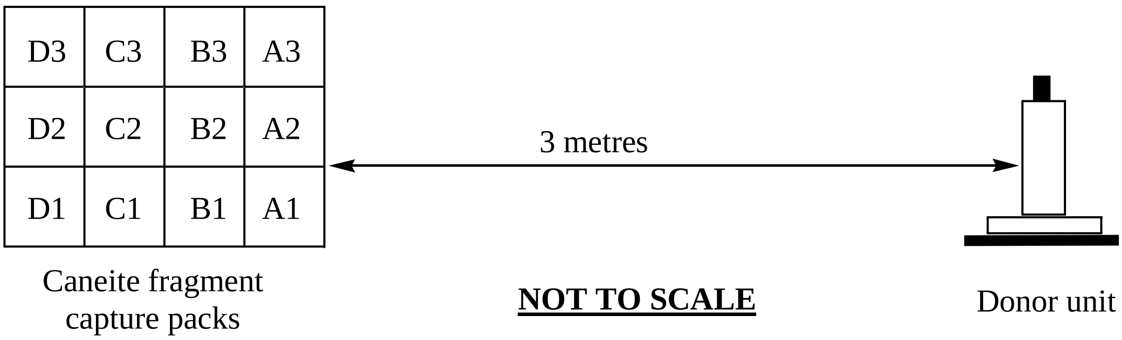


Figure 5. Fragment capture test configuration

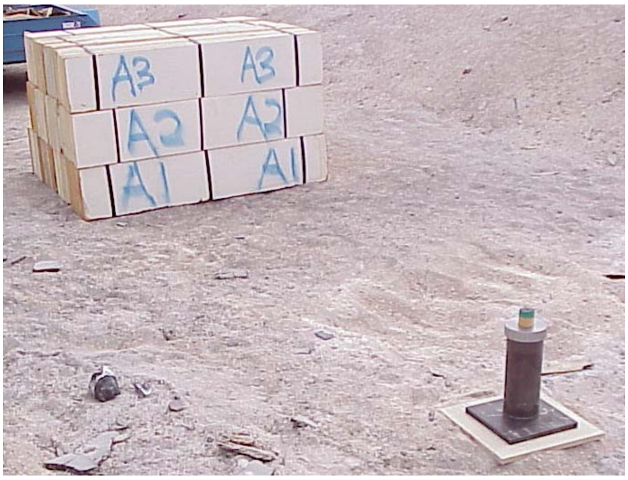


Figure 6. Fragment capture test configuration

5. Results and Discussion

5.1 Side Initiation Experiments

As shown in the photographs of the witness plates (Figures 7a & b), the generic test units initiated by boosters mounted on the side of the units detonated in such a way that a clean hole was formed in the witness plates. This indicated that, in the sympathetic reaction test configuration, an acceptor charge that detonated following side initiation should cause formation of a clean hole in the witness plate allowing accurate assessment of the reaction type.

Figure 7a & b. Witness plates from side initiation tests

5.2 Fragment Penetration Experiments

This experiment confirmed that the maximum standoff distance at which fragments from the donor charge penetrate 9.5 mm mild steel (wall thickness of the acceptors) (Table 3) is dramatically in excess of the separation distances in the sympathetic detonation test configuration (Table 5). Clearly, fragment penetration is not the only contributing factor to sympathetic reaction of cased charges.

Table 3. Results from fragment penetration experiments

Plate Size	Distance (m)[1]	Description
Small	0.24	Plate not found
Small	0.36	Major penetration and tearing, pieces recovered at 200m.
Large	1.2	Multiple penetrations, plate buckled & propelled 100m.
Large	2	Multiple penetrations, plate propelled 40m.
Large	3	Multiple penetrations
Large	4	Several penetrations
Large	5	Several penetrations, no large fragments impacted plate
Large	6.5	Two penetrations, no large fragments impacted plate
Large	8.7	Two small fragments impacted plate, no penetration

[1] Distance between donor GTU edge and witness plate.

Figure 8a - c. Penetration of witness plates at 0.36, 1.2 and 5 metres

5.3 Fragment Capture Experiment

Fragments were found in all of the first two layers of fragment packs and also in the third pack at ground level (C1). The fragments were collected, cleaned, weighed and photographed. Fragment distribution is detailed in Table 4 with photographs reproduced in Figures 9a & b and Appendix B. The fragmentation was considered typical of naturally fragmenting steel.

In hindsight, it would have been preferable to have the charge elevated relative to the fragment packs as the top-initiated charge directed the fragments at a downward angle. This resulted in the majority of fragments being found in the packs at ground level and

undoubtedly many fragments impacting the ground rather than reaching the stack of packs.

As there was no relationship between the fragment penetration cut-off point (Section 5.2) and the response of acceptors at typical standoff distance, no additional analysis was performed on the recovered fragments.

Table 4. Fragments recovered from fragment capture packs

Pack	Fragments		
	Quantity	Total Weight (g)	Heaviest (g)
A1	55	71	8
A2	38	85	19
A3	25	70	13
B1	24	142	17
B2	4	31	17
B3	2	48	45
C1	1	14	14

Figure 9a & b. Images of typical fragments recovered (from packs A1 and B1)

5.4 Sympathetic Reaction Experiments

Results from the sympathetic reaction experiments are summarised in Table 5. The responses are classified according to the internationally accepted convention as described in DI(G) LOG 07-10 [17], that is:

Reaction Type I – Detonation reaction
Reaction Type II – Partial detonation reaction
Reaction Type III – Explosion reaction
Reaction Type IV – Deflagration reaction
Reaction Type V – Burning reaction

Table 5. Acceptor responses (reaction types) in sympathetic reaction tests

Standoff Distance (mm) [1]	Acceptor Response (Reaction Type)		
	PBXN-109	ARX-2014/M1	ARX-2014/M5
120	I, I	I, I	I
180	I, I	I, II, III	I, III
240	I, II	II, III, IV	III, III
300	II	III, V	III
360	II, IV	III, IV	
420	IV		
600	V		
960	V		

[1] distance from edge of donor GTU to edge of acceptor GTU

The standoff distances between donor and acceptor charges were based on the external diameter (120 mm) of a GTU and advanced in ½ diameter increments (60 mm). A limited number of acceptor charges were available for the experiments – 12 each for PBXN-109 and ARX-2014/M1 and just 6 for ARX-2014/M5.

The reaction type of the acceptors was assigned based on the condition of the witness plates, any recovered sections of GTU and any recovered PBX (undamaged or burnt). Examples of the results are shown in Figures 10-13.

Figure 10a & b. Reaction Types IV, I and I (left to right). Unconsumed PBX is from the Type IV reaction

Figure 11. Reaction Types II and V (l to r)

Figure 12. Reaction Types III and II (l to r)

Figure 13a & b. Examples of Type V reactions showing both unconsumed and burnt PBX

Figure 13c. Example of Type V reactions

Some caution must be used during interpretation of the results as many more tests would be required to increase statistical confidence. Within this limitation, it is reasonable to state that the experiment indicates a difference in response of the acceptors containing RS-RDX based formulations compared with standard PBXN-109. The differences can be described in two ways based on a reaction type of III or better being a pass:

- Firstly, for both ADI and SNPE RS-RDX formulations, the minimum separation at which a pass was obtained was 180 mm. This is a significant improvement compared with 360 mm for the standard PBXN-109 formulation. It must be noted that there were also test failures at these distances for all formulations.

- Alternatively, examining separations where only pass results were observed, PBXN-109 passes at 420 mm, ARX-2014/M1 passes at 300mm and ARX-2014/M5 passes at 240 mm. Again, this interpretation clearly favours the use of reduced sensitivity RDX grades.

While there is insufficient data to categorically state whether or not the two formulations containing the reduced sensitivity RDX grades had identical response levels in this test configuration, they are certainly similar.

Overall, it is reasonable to state that the standoff distance to achieve a pass reaction in this configuration is 240-300 mm for the acceptors with reduced sensitivity grades of RDX in the formulation, compared with a distance greater than 360 mm for the conventional RDX formulation.

6. Conclusions

Despite the limited number of results available from this series of tests, it can be concluded that the use of reduced sensitivity grades of RDX in PBXN-109 formulations does have benefits in sympathetic reaction scenarios, at least in this test configuration. What remains unknown are both the magnitude of the benefit and the effect of scale - whether this benefit would be significant for ordnance items containing higher quantities of explosives and/or having increased wall thickness. It is hoped that the use of RS-RDX in PBX warhead fills could provide part of a system solution, in conjunction with mitigation techniques, to achieve compliance with sympathetic reaction requirements.

7. Acknowledgements

This work was partially supported by funding from ADI Limited through the ADI-DSTO Collaborative Work Programme. The assistance of Tim Miller from ADI Ltd is gratefully acknowledged. The authors would also like to recognise the support that John Symes, Max Joyner, Bob Arbon and Alan Starks provided in charge preparation and the staff at Proof and Experimental Establishment Pt Wakefield for assistance during the field trials. DSTO Scientific and Engineering Services were responsible for the design and manufacture of the generic test units and performed this work to their usual high standards.

8. References

1. Lochert, I.J., Franson, M.D., and Hamshere, B.L. *Reduced Sensitivity RDX Part I: Literature Review and DSTO Evaluation.* DSTO-TR-1447, (2003), DSTO.
2. Freche, A., Spyckerelle, C., and Lecume, S. *SNPE Insensitive Nitramines*, Insensitive Munitions and Energetic Materials Technology Symposium (2003), Orlando, Florida.
3. Lecume, S., Chabin, P., and Brunet, P. *Two RDX Qualities for PBXN-109 Formulation Sensitivity Comparison*, 2001 Insensitive Munitions and Energetic Materials Symposium (2001), Bordeaux.
4. Lochert, I.J., Dexter, R.M., and Hamshere, B.L. *Evaluation of Australian RDX in PBXN-109.* DSTO-TN-0440, (2002), DSTO.
5. Lochert, I.J., Franson, M.D., and Hamshere, B.L. *Assessment of Australian Insensitive RDX*, Insensitive Munitions and Energetic Materials Technology Symposium (2003), Orlando, Florida.
6. *Australian Defence Standard Def(Aust)5382B RDX: Specification*. (1996), Australian Defence Department.
7. Freche, A., Aviles, J., Donnio, L., and Spyckerelle, C. *Insensitive RDX (I-RDX)*, Insensitive Munitions and Energetic Materials Symposium - Technology Implementation in the 21st Century (2000), San Antonio, Texas.
8. Lu, J.P., Lochert, I.J., Kennedy, D.L., and Hamshere, B.L. *Simulation of Sympathetic Reaction Tests for PBXN-109*, 13th International Detonation Symposium (2006), Norfolk VA USA.
9. Franson, M.D., Lochert, I.J., and Hamshere, B.L. *DSTO Evaluation of Reduced Sensitivity RDX (RS-RDX)*, Parari, Sixth Australian Ordnance Symposium (2003), Canberra, Australia.
10. Scholtes, G. and van der Heijden, A. *IM-Related and Laboratory Scale Testing on I-RDX and RDX-Based Explosives*, Insensitive Munitions and Energetic Materials Technology Symposium (2004), San Francisco, California.
11. Sutherland, G., Schlegel, E., Caulder, S., O'Connor, J., and Lemar, R. *Detonation Properties of Two Research Explosives - One Containing RDX and One Containing Insensitive RDX*, Insensitive Munitions and Energetic Materials Technology Symposium (2004), San Francisco, California.
12. Spyckerelle, C., Freche, A., and Eck, G. *Ageing of I-RDX and of compositions based on I-RDX*, Insensitive Munitions and Energetic Materials Technology Symposium (2004), San Francisco, California.
13. Doherty, R.M., Nock, L.A., and Watt, D.S. *Reduced Sensitivity RDX Round Robin Programme - Update*, 37th International Annual Conference of ICT on Energetic Materials (2006), Karlsruhe, Germany.
14. Doherty, R.M. and Watt, D.S. *Reduced Sensitivity RDX, Round Robin Program*, Insensitive Munitions and Energetic Materials Technology Symposium (2004), San Francisco, California.
15. Kristiansen, J.D., Johansen, Ø.H., Berg, A., Halvorsen, T., Gjersøe, R., Smith, K.-T., and Christensen, M. *Steps towards reduced sensitivity HMX (RS-HMX): Reduced shock sensitivity in both Cast-Cured and Pressable PBX compositions.*, Insensitive Munitions and Energetic Materials Technology Symposium (2004), San Francisco, California.

16. *Military Standard. Hazard Assessment Tests for Non-Nuclear Munitions - superseded by 2105C (2003)*, *MIL-STD-2105B*. (1994).
17. *Defence Instructions (General) LOG 07-10. Insensitive Munitions.*, *DI(G) LOG 07-10*. (2005).
18. Higgins, S.G. *Insensitive Munitions Plan Of Action And Milestones (POA&M) - Penguin [Penguin IM Plan].* (1993), Department of Navy.

Appendix A: Sympathetic Reaction of Uncased Charges

A.1. Introduction

Following the sympathetic reaction studies on cased PBX charges, a requirement was identified to perform a similar study on uncased PBX charges to support the modelling programme at DSTO. The objective this time was not to investigate potential benefits of using reduced sensitivity RDX in cast-cured PBX, but rather to generate data to validate a DSTO-developed ignition and growth model [A1] for PBXN-109.

A.2. Experimental

A.2.1 Hardware and Materials

The uncased charges were prepared to the same dimensions as those cast into the GTUs by casting the PBX into metal split moulds coated with a release agent. The metal moulds were removed from the charges after cure and the charges cut to length (300 mm).

There was insufficient CXM-7 available to fill all of the uncased PBXN-109 charges required and the shortfall was addressed by producing those charges to be used as donors from a combination of Dyno Nobel RDX Type II, Class 1 (lot DDP01J001-42) and RO Bridgwater RDX Type II, Class 5 (lot unknown). The aluminium (75L), isocyanate and dioctyl adipate used for all the uncased charges were as discussed in Section 3.2.2 of this document.

The witness plates beneath the charges were 20 mm thick x 270 x 270 mm 250 grade mild steel plate.

A.2.2 Trial Outline

The sympathetic reaction tests were performed in the same manner as described in Section 4 of this document. Figures 2 and A1 depict the experimental configuration.

Figure A1. Sympathetic reaction trial configuration (uncased charges)

A.3. Results and Discussion

As with the cased charges, the responses of the acceptors are classified according to the international convention outlined in [A2]. The results are summarised in Table A1.

Table A1. Acceptor responses (reaction types) in sympathetic reaction tests (uncased charges)

Standoff Distance (mm)[1]	Reaction Type
10	I
20	I
40	I
60	III, III
79	III, III
139	III
199	III
259	III

[1]distance from edge of donor to edge of acceptor

Although the deformation to the witness plates was very minor for the three largest separation distances tested, adherence to the response definitions indicated a Type III reaction. Examples of the results are shown in Figures A2 and A3.

Figure A2. Reaction Type III

Figure A3. Reaction Type I

Whilst the primary objective of these experiments was to generate data for modelling activities, it is appropriate to compare the results of the cased and uncased PBXN-109 charges[1]. As expected, the uncased charges achieved a passing result (Type III response or better) at much closer separation distances. At all directly comparable distances, the uncased acceptors had a Type III reaction whilst the cased charges were either Type I or II. Further experiments would be required to ascertain whether the higher violence of reaction of the cased acceptors is due to the fragments from the donor, the confinement of the acceptor or a combination of the two factors.

Consideration of all results in this report (cased and uncased sympathetic reaction, as well as the fragmentation penetration experiments) clearly demonstrate that sympathetic reaction of cased charges is a complex event involving both shock initiation and case effects – fragments from the donor and/or confinement of the acceptor.

The modelling studies associated with this work are ongoing however preliminary results have been reported [A3]. Future plans in the modelling area include an examination of the cased sympathetic reaction experiments detailed in this report.

A.4. References

A1. Lu, J.P. and Kennedy, D.L. *Ignition and Growth Model Development for PBXN-109.* DSTO-TR-1726, (2005), DSTO.

A2. *Defence Instructions (General) LOG 07-10. Insensitive Munitions., DI(G) LOG 07-10.* (2005), Australian Defence Department.

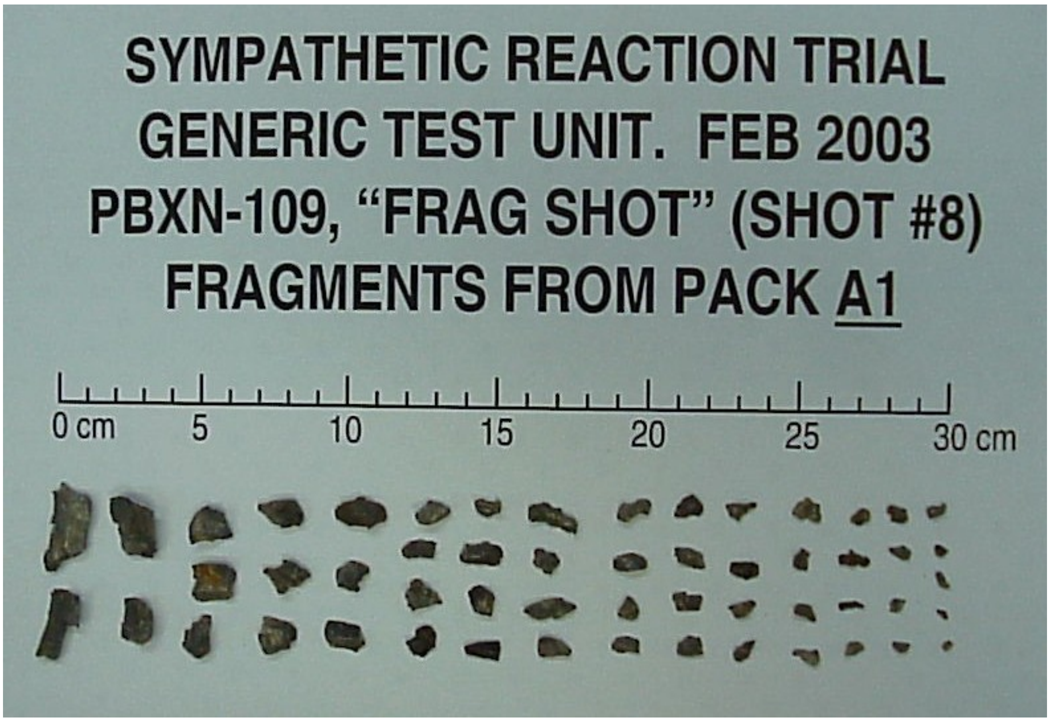
A3. Lu, J.P., Lochert, I.J., Kennedy, D.L., and Hamshere, B.L. *Simulation of Sympathetic Reaction Tests for PBXN-109*, 13th International Detonation Symposium (2006), Norfolk Virginia.

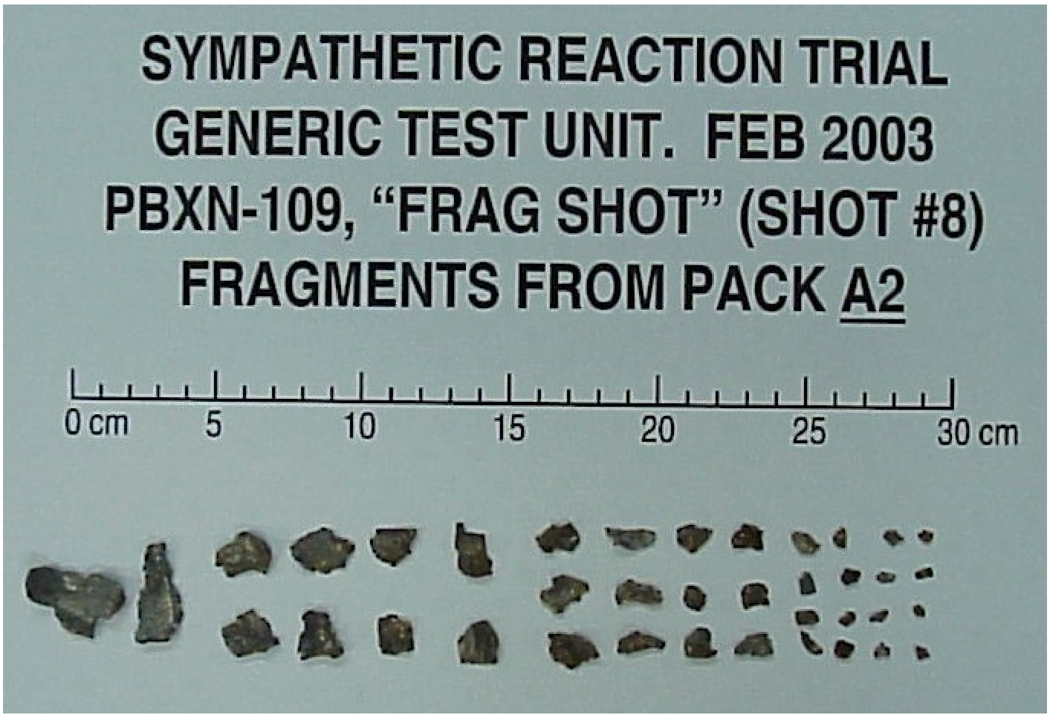
---

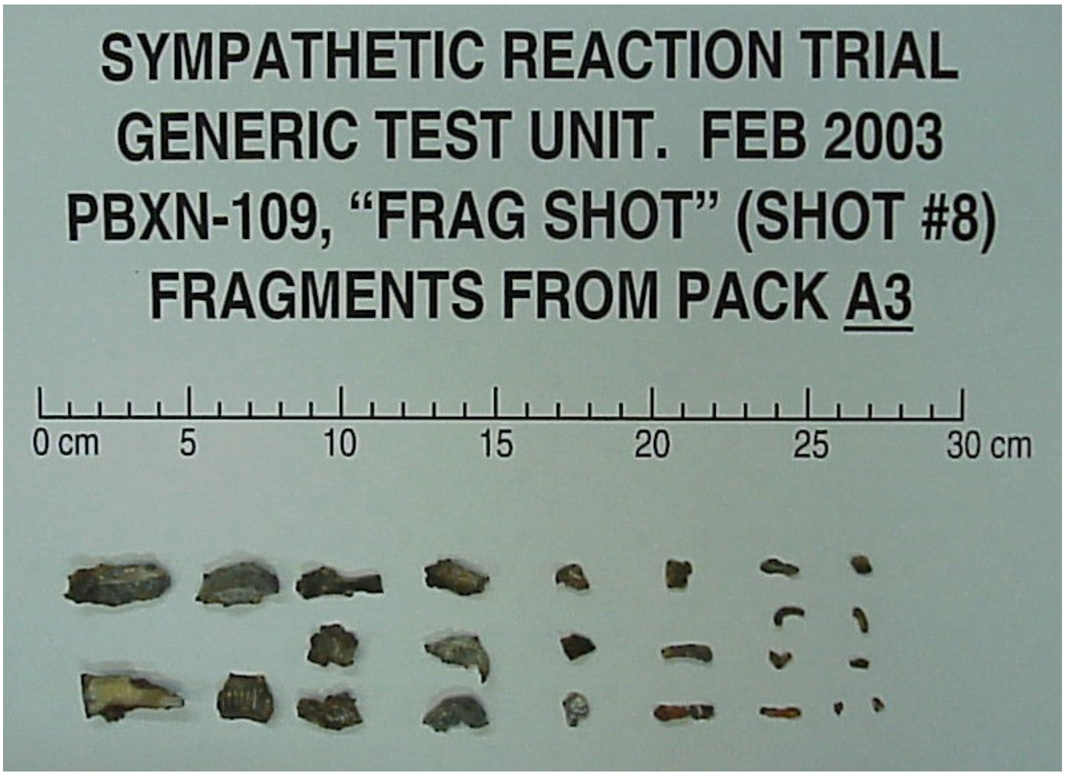
[1] When comparing the cased and uncased experiments it is important to remember that the standoff distances are edge-edge, not centre-centre, and are therefore different due to the case thickness of the GTUs. To identify the comparable experiments subtract 19mm from the edge-edge standoff distance of the uncased charges.

Appendix B: Images of Recovered Fragments

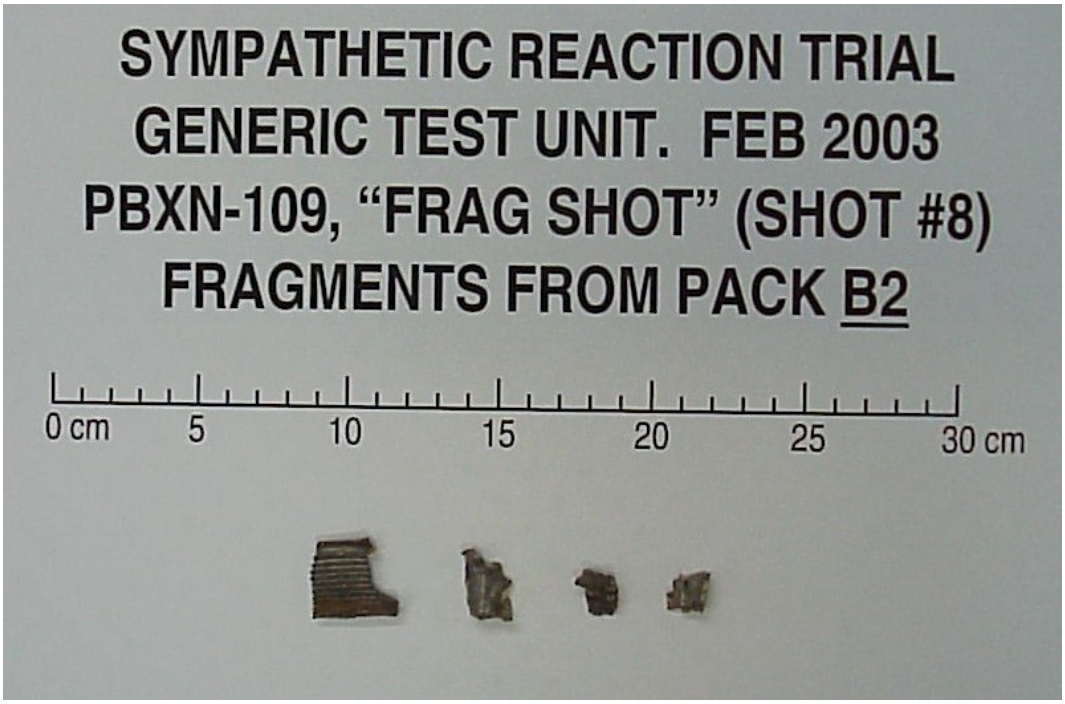
The images below show the fragments from the fragment capture experiment described in Sections 4.2.2 and 5.2. Fragments were found in all caneite packs except C2 and C3.

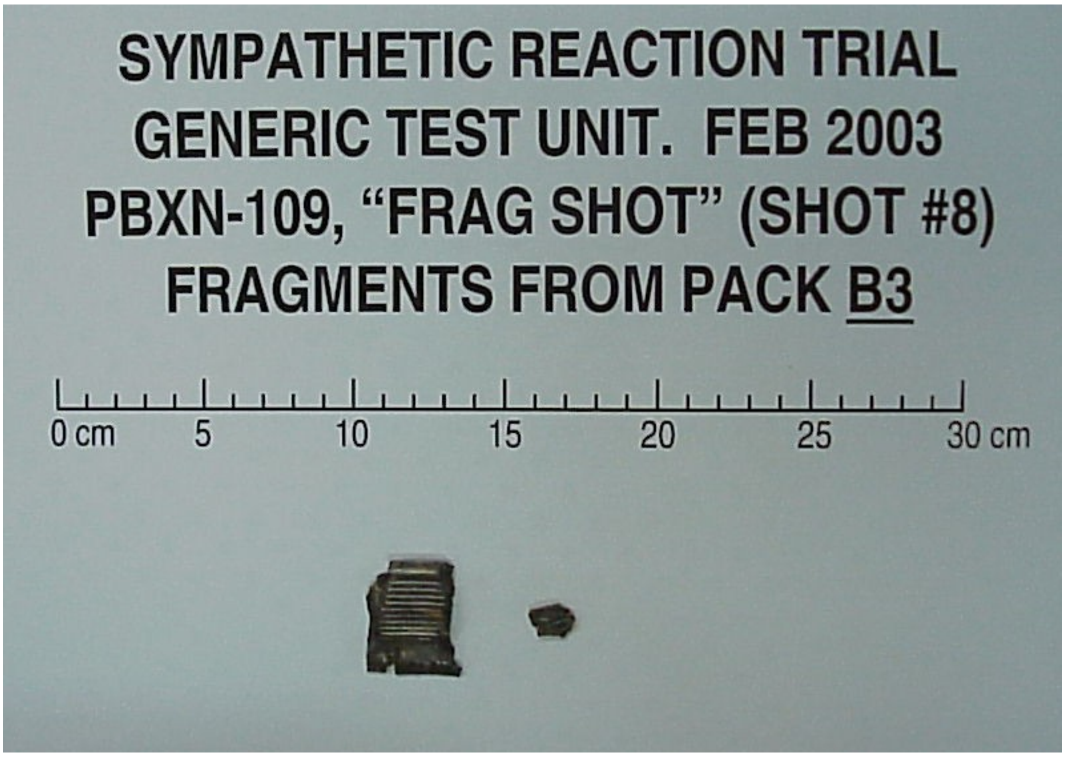


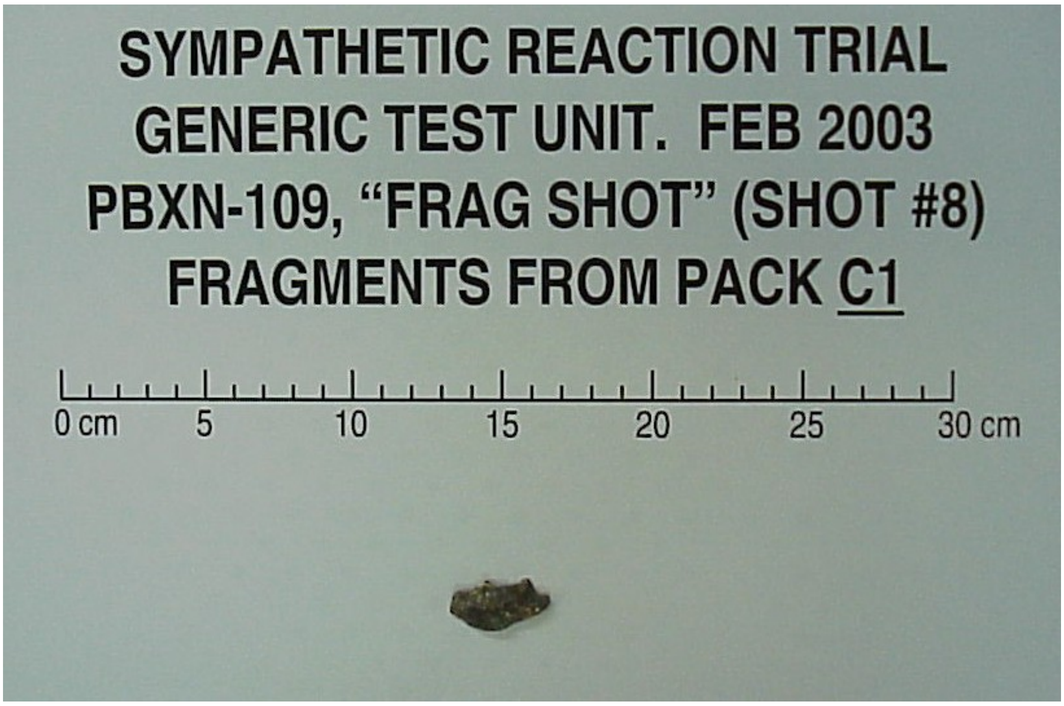



SYMPATHETIC REACTION TRIAL
GENERIC TEST UNIT. FEB 2003
PBXN-109, "FRAG SHOT" (SHOT #8)
FRAGMENTS FROM PACK A3
0 cm
5
10
15
20
25
30 cm


SYMPATHETIC REACTION TRIAL
GENERIC TEST UNIT. FEB 2003
PBXN-109, "FRAG SHOT" (SHOT #8)
FRAGMENTS FROM PACK B1
0 cm
5
10
15
20
25
30 cm


SYMPATHETIC REACTION TRIAL
GENERIC TEST UNIT. FEB 2003
PBXN-109, "FRAG SHOT" (SHOT #8)
FRAGMENTS FROM PACK B2
0 cm 5 10 15 20 25 30 cm


SYMPATHETIC REACTION TRIAL
GENERIC TEST UNIT. FEB 2003
PBXN-109, "FRAG SHOT" (SHOT #8)
FRAGMENTS FROM PACK B3
0 cm 5 10 15 20 25 30 cm


SYMPATHETIC REACTION TRIAL
GENERIC TEST UNIT. FEB 2003
PBXN-109, "FRAG SHOT" (SHOT #8)
FRAGMENTS FROM PACK C1
0 cm
5
10
15
20
25
30 cm

DISTRIBUTION LIST

"As per the Research Library's *Policy on electronic distribution of official series reports* (http://web-vic.dsto.defence.gov.au/workareas/library/aboutrl/roles&policies/mission.htm) Unclassified (both Public Release and Limited), xxx-in-confidence and Restricted reports and their document data sheets will be sent by email through DRN to all recipients with Australian defence email accounts who are on the distribution list apart from the author(s) and the task sponsor(s). Other addressees and Libraries and Archives will also receive hardcopies."

Reduced Sensitivity RDX (RS-RDX) Part II: Sympathetic Reaction

Ian J. Lochert, Mark D. Franson and Brian L. Hamshere

AUSTRALIA

DEFENCE ORGANISATION	**No. of copies**
Task Sponsor	
COMAUSNAVAIRGRP	1 Printed
S&T Program	
Chief Defence Scientist	1
Deputy Chief Defence Scientist Policy	1
AS Science Corporate Management	1
Director General Science Policy Development	1
Counsellor Defence Science, London	Doc Data Sheet
Counsellor Defence Science, Washington	Doc Data Sheet
Scientific Adviser to MRDC, Thailand	Doc Data Sheet
Scientific Adviser Joint	1
Navy Scientific Adviser	1
Scientific Adviser – Army	Doc Data Sheet & Dist List
Air Force Scientific Adviser	1
Scientific Adviser to the DMO	1
Systems Sciences Laboratory	
Chief of Weapons Systems Division	Doc Data Sht & Dist List
Research Leader Maritime Weapons Systems	Doc Data Sht & Dist List
Head Explosives & Pyrotechnics Group	1
Task Manager – Robin Baker	1
Author: Ian Lochert	1 Printed
Author: Mark Franson	1 Printed
Phil Davies (WSD)	1
Jing Ping Lu	1
Arthur Provatas	1
Merran Daniel	1

Matthew Smith	1
DSTO Library and Archives	
Library Fishermans Bend	Doc Data Sheet
Library Edinburgh	2 printed
Defence Archives	1 printed
Capability Development Group	
Director General Maritime Development	1
Director General Capability and Plans	Doc Data Sheet
Assistant Secretary Investment Analysis	Doc Data Sheet
Director Capability Plans and Programming	Doc Data Sheet
Chief Information Officer Group	
Head Information Capability Management Division	Doc Data Sheet
Director General Australian Defence Simulation Office	Doc Data Sheet
AS Information Strategy and Futures	Doc Data Sheet
Director General Information Services	Doc Data Sheet
Strategy Executive	
Assistant Secretary Strategic Planning	Doc Data Sheet
Assistant Secretary International and Domestic Security Policy	Doc Data Sheet
Navy	
Commander Australian Navy Mine Warfare Clearance Diving Group	1
SOPOLDEV COMAUSNAVMCDGRP	1
Maritime Operational Analysis Centre, Building 89/90 Garden Island Sydney NSW Deputy Director (Operations) Deputy Director (Analysis)	Doc Data Sht & Dist List
Director General Navy Capability, Performance and Plans, Navy Headquarters	Doc Data Sheet
Director General Navy Strategic Policy and Futures, Navy Headquarters	Doc Data Sheet
Air Force	
SO (Science) - Headquarters Air Combat Group, RAAF Base, Williamtown NSW 2314	Doc Data Sht & Exec Summ
Staff Officer Surveillance and Response Group	Doc Data Sht & Exec Summ
Army	
Australian National Coordination Officer ABCA (AS NCO ABCA), Land Warfare Development Centre, Puckapunyal	Doc Data Sheet
J86 (TCS GROUP), DJFHQ	Doc Data Sheet
SO (Science) - Land Headquarters (LHQ), Victoria Barracks NSW	Doc Data Sht & Exec Summary
SO (Science) - Special Operations Command (SOCOMD), R5-SB-15, Russell Offices Canberra	Doc Data Sht & Exec Summary & Dist List
SO (Science), Deployable Joint Force Headquarters (DJFHQ) (L),	Doc Data Sheet

Enoggera QLD

Joint Operations Command

Director General Joint Operations	Doc Data Sheet
Chief of Staff Headquarters Joint Operations Command	Doc Data Sheet
Commandant ADF Warfare Centre	Doc Data Sheet
Director General Strategic Logistics	Doc Data Sheet
COS Australian Defence College	Doc Data Sheet
Cdr Joint Logistics Command	Doc Data Sheet
Director, Ordnance Safety	1
TSO-N Directorate Ordnance Safety	1

Intelligence and Security Group

AS Concepts, Capability and Resources	1
DGSTA, Defence Intelligence Organisation	1 Printed
Manager, Information Centre, Defence Intelligence Organisation	1
Director Advanced Capabilities	Doc Data Sheet

Defence Materiel Organisation

Deputy CEO	Doc Data Sheet
Head Aerospace Systems Division	1
Head Maritime Systems Division	1
Program Manager Air Warfare Destroyer	Doc Data Sheet
Guided Weapon & Explosive Ordnance Branch (GWEO)	1
Deputy Director Projects (GWEO)	1
Guided Weapons Acquisition Branch (GWA)	1

OTHER ORGANISATIONS

National Library of Australia	1
NASA (Canberra)	1
Thales Australia (Mulwala) Attn: Mr David Ridderhof (david.ridderhof@thalesgroup.com.au)	1

UNIVERSITIES AND COLLEGES
Australian Defence Force Academy

Library	1
Head of Aerospace and Mechanical Engineering	1
Hargrave Library, Monash University	Doc Data Sheet

OUTSIDE AUSTRALIA

INTERNATIONAL DEFENCE INFORMATION CENTRES

US Defense Technical Information Center	1
UK Dstl Knowledge Services	1
Canada Defence Research Directorate R&D Knowledge & Information Management (DRDKIM)	1
NZ Defence Information Centre	1
Munitions Safety Information Analysis Center (msiac@msiac.nato.int)	

ABSTRACTING AND INFORMATION ORGANISATIONS

Library, Chemical Abstracts Reference Service	1
Engineering Societies Library, US	1
Materials Information, Cambridge Scientific Abstracts, US	1
Documents Librarian, The Center for Research Libraries, US	1
SPARES	5 Printed

Total number of copies: 52 Printed: 12 PDF: 40

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION DOCUMENT CONTROL DATA	1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)
Reduced Sensitivity RDX (RS-RDX) Part II: Sympathetic Reaction	Document (U) Title (U) Abstract (U)
4. AUTHOR(S)	5. CORPORATE AUTHOR
Ian J. Lochert, Mark D. Franson and Brian L. Hamshere	DSTO Defence Science and Technology Organisation PO Box 1500 Edinburgh South Australia 5111 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TR-1941	AR-013-794	Technical Report	November 2006

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
E9505-25-158/1	NAV 03/274	COMAUSNAVAIRGRP	26	19

13. URL on the World Wide Web	14. RELEASE AUTHORITY
http://www.dsto.defence.gov.au/corporate/reports/DSTO-TR-1941.pdf	Chief, Weapons Systems Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE, PO BOX 1500, EDINBURGH, SA 5111

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CITATION IN OTHER DOCUMENTS Yes

18. DEFTEST DESCRIPTORS

RDX, insensitive munitions, polymer-bonded explosives, sympathetic reaction

19. ABSTRACT

Australian-manufactured Grade A RDX has been proven to be a Reduced Sensitivity grade of RDX. That is, when used in cast-cured PBX formulations, the PBX is intrinsically less sensitive to shock stimuli than if conventional RDX is used. The implications for insensitive munitions compliance may be significant, particularly in sympathetic reaction scenarios. This work assesses the sympathetic response of ADI Grade A RDX in a standard polymer-bonded explosive formulation in a generic test unit and compares it with formulations containing RDX produced by SNPE (France) and Dyno Nobel (Norway). Additional work was performed to assess the sympathetic reaction of uncased charges of PBXN-109 containing standard Type II RDX. This data was primarily required for modelling studies.